A Partnership for Modeling the Marine Environment of Puget Sound, Washington – Puget Sound Naval Shipyard/Space and Naval Warfare Systems Center Report

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LONG-TERM GOALS

Estuaries, fjords and sounds are important, major components of marine ecosystems worldwide. Because of this, and their generally poor treatment by man, large estuaries should be the focus of large-scale, multidisciplinary, integrative modeling efforts. We need to both understand how these systems work, and be able to predict how they will respond to changes, whether natural or anthropogenic. Puget Sound, Washington State's largest inland sea, is both the largest fjord in the lower forty-eight states and closest to the substantial urban centers of Seattle, Tacoma, Everett, Bremerton and surrounding communities. Relative to other coastal systems, Pacific Northwest fjords have seasonally high annual phytoplankton standing stock and primary production, and they support several economically valuable fisheries. Our long-term goals are to develop quantitative understanding of the seasonal and longer time-scale variability of the Sound's circulation, roles of water column stratification, nutrients, and light (and their interactions) on phytoplankton and zooplankton dynamics, and the sensitivity of the physical and the biological system to natural and human perturbations. We will develop models of Puget Sound that can aid agencies with responsibilities for environmental management in making informed decisions and serve as marine science education tools. A special emphasis for this component of the project is to develop an inlet-scale integrated modeling system that will include the hydrodynamic and contaminant transport within the receiving waters of Sinclair and Dyes Inlets, the surrounding watershed, and the boundaries with the Greater Puget Sound System.

OBJECTIVES

The Partnership for Modeling the Marine Environment of Puget Sound consists of five separate organizations: University of Washington (School of Oceanography and College of Education), King County Department of Natural Resources, Washington State Department of Ecology, Puget Sound Naval Shipyard/Space and Naval Warfare Systems Center (PSNS/SPAWAR), and Ocean Inquiry Project. The partnership will develop, maintain and operate a system of flexibly linked simulation models of the Puget Sound's circulation and ecosystem, a data management system for archiving and

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exchanging oceanographic data and model results that are accessible to all members of the partnership as well as to the regional and oceanographic community, and an effective delivery interface for the model results and observational data for research, education and policy formulation. The partnership engages in research activities aimed at developing fundamental understanding of the Sound's working, as well as addressing practical questions raised by the regional community concerning management of the Sound and its resources. The partnership will function as an estuarine research node within the NOPP Ocean Information Commons.

APPROACH

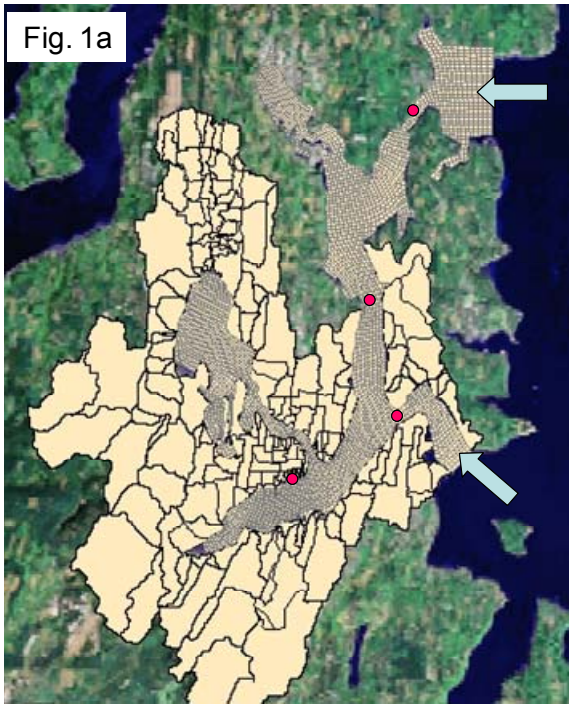
The partnership is administered from School of Oceanography, University of Washington. The lead P.I. (Kawase) will be responsible for project oversight and coordination. Under tasking from the Puget Sound Naval Shipyard, the Space and Naval Warfare Systems Center is conducting modeling studies to develop an Inlet-scale integrated modeling capability for the Sinclair and Dyes Inlet watershed [1] to support the development of Total Maximum Daily Load (TMDL) studies [2] and water clean up plans for the Inlets [3]. The final modeling product will provide the capability to simulate, on an Inlet-scale basis, various risk management and policy alternatives. Drs. Johnston and Wang will be coordinating with the partnership on aspects of coupling the Inlet-scale model with the larger scale Puget Sound model, sharing data and information, and visualizing model simulations and results. Current work includes implementing the linkage between Sinclair and Dyes Inlet and the sound-scale model, developing model analysis tools that utilize the common data format (netCDF-network Common Data Form) model output, and verifying model predictions with current data.

WORK COMPLETED

During the FY2006 reporting period the PSNS/SPAWAR partners have successfully completed a joint current meter study with Ecology partners for Agate, Port Orchard and Rich Passages, extracted data from the POM output for input as boundary conditions for the Sinclair/Dyes Inlet model, developed a set of analysis tools to process model output, and implemented the linkage between the models. Work is continuing on making the CH3D model output compatible with available model analysis tools and accessible to other PSMEM partners (Figure 1).

RESULTS

One-way coupling between the Puget Sound POM and CH3D was implemented using simulation results from selected Puget Sound POM nodes located near the boundaries of the CH3D numerical grid (Fig. 1). A data extraction tool for the Puget Sound POM,



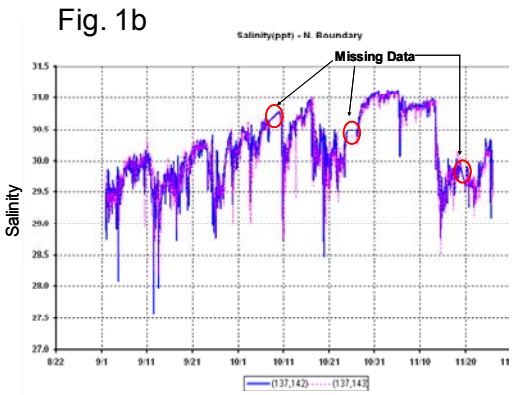


Fig 1a. (left) CH3D model grid for the Sinclair/Dyes Inlet system showing model boundaries (arrows) and current meter mooring locations (red circles).

Fig 1b (right). Example of salinity data from POM model used for boundary input to CH3D.

utilizing the OPeNDAP protocol was developed [4] to extract the data needed to simulate currents and mixing for the Fall 2005 sampling period (Fig. 1b). The current meter data obtained from the ACDPs deployed in the in Inlets during the Fall 2005 [5] are being used to evaluate model performance (Fig. 2). Previously, the netCDF (network Common Data Form, Unidata Program Center [6]) format was implemented for CH3D to standardize model output. The capability to produce netCDF output has facilitated the development of a General User Interface (GUI) tool for processing and displaying CH3D model results using Matlab [4]. The tool makes it possible to evaluate model results at each node and depth and generate time series and animations of model results. The tool includes features that allow the user to zoom, view tidal elevations at selected nodes, and generate time series of model results (Fig. 3). Examples of netCDF output from the CH3D model and animations of simulation results can be accessed at www.psmem.org/ models/psns-spawar.html.

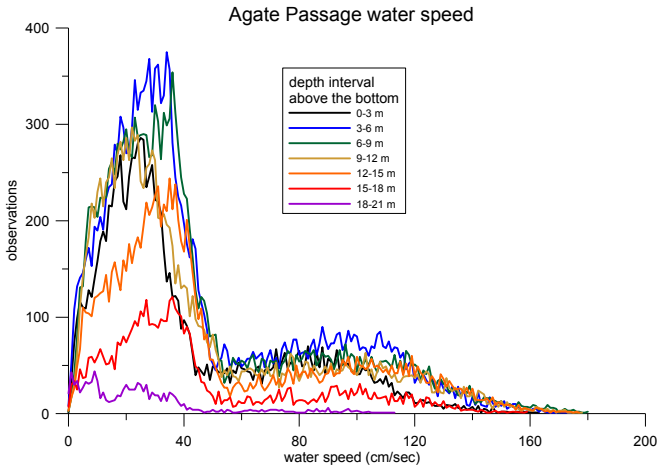


Fig. 2. Current speeds for 3-m depth bins observed in Agate Passage during Fall 2005.

The modeling framework for Sinclair and Dyes Inlets was also set up to simulate the hydrological and tidal conditions present during the release of hatchery-reared, juvenile Chinook salmon from the Gorst Creek Hatchery (May 19 - Jun 30, 2002) during a catch and release out migration sampling study conducted in Sinclair Inlet [7]. The model simulated the release of a conservative "tracer" that corresponded to when the majority of the marked fish were released into Gorst Creek. The model results were compared to fish recapture rates to evaluate differences between fish density and the tracer concentrations predicted by the model [8]. Ongoing work is continuing to implement sequential runs for one-way forcing of CH3D and refine the tools for processing model output.

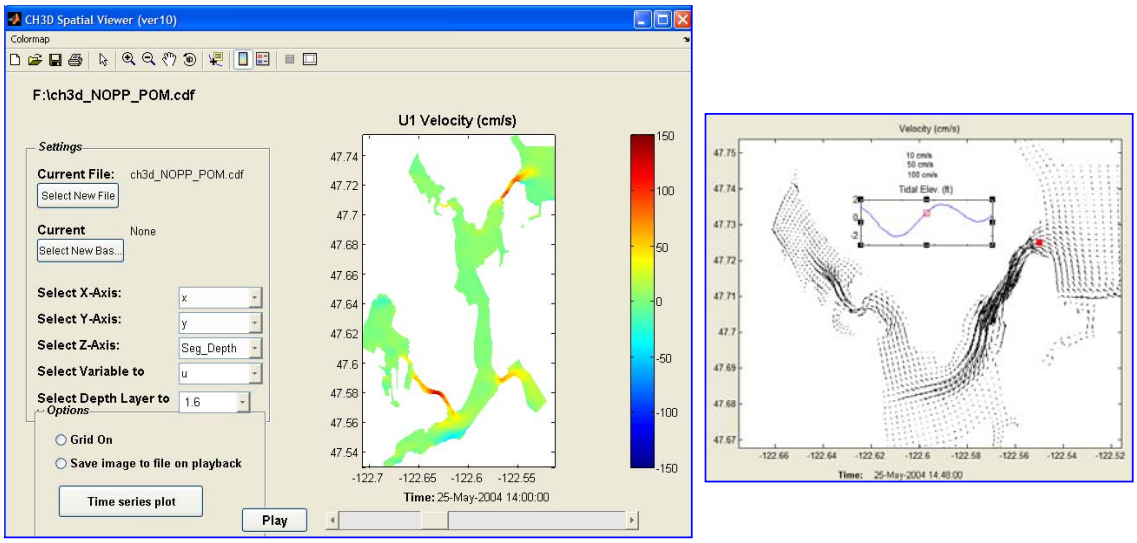


Fig. 3. Example output from the MatLab GUI showing current velocity throughout the model domain (left figure) and a close up of current velocity vectors in Agate Passage and Liberty Bay (right figure).

IMPACT/APPLICATIONS

National Security. An improved modeling capability of the circulation and marine ecosystem of Puget Sound at both the sound- and inlet-scale will help local and regional governments develop more effective measures for protecting marine resources and economic assets of the Puget Sound that are vital to our National Security.

Economic Development. Predictive modeling of Puget Sound's circulation and marine ecosystem will have positive impacts on many economic activities taking place in the Sound, including forecasting of harmful algal blooms (HABs), understanding of hypoxia-events, and tracking long term variability in water quality.

Quality of Life. The quality of life in the Puget Sound region is directly related to the quality of our environment. Our models, by predicting responses from oceanographic processes and other events will help Coast Guard and regional law-enforcement agencies with search and rescue operations and containment of contaminant spills, and information about tides and currents is of vital interest to boaters and fishermen.

Science Education and Communication. Visualizations, support material, and curriculum modules based on the model results will be a valuable tool for learning about Puget Sound's marine environment in classroom, in museums, and through the web.

TRANSITIONS

The models for Sinclair and Dyes Inlets are being used by the Washington State Department of Ecology to establish TMDLs for the Inlets [3] and Department of Fish and Wildlife to evaluate fish out migration [7].

RELATED PROJECTS

This work compliments work being conducted under PSNS & IMF Project ENVVEST [1] to conduct modeling studies of the Sinclair and Dyes Inlet Watershed to assess water quality of the Inlets [3] and support the development of TMDLs for the watershed [2, 3]. Modeling study results are also being used by the WDFW to evaluate out migration of Chinook salmon in Sinclair Inlet [7].

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PUBLICATIONS

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